

APPLICATIONS OF NANOTECHNOLOGY IN CONSTRUCTION INDUSTRY

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ABSTRACT

Nanotechnology in science, engineering and technology represents the study of phenomena and the manipulation of materials at nanoscale, which is about 1 to 100 nanometers. At nanoscale, the properties of materials are dramatically improved from the properties of individual atoms due to increase in relative surface area and quantum effects. The construction industry is a new field for nanotechnology and is growing rapidly for the last few years. Nanotechnology based products can improve the current construction materials. Nanotechnology in construction is mainly focused on concrete having better properties using different nanomaterials, steel having better physical properties using copper nanoparticles and nano-sensors for construction. Although these materials are having unique properties but some of their limitations are adverse effect on environment and health. Therefore it is utmost necessary to examine and estimates the risk from its production, use and disposal. In this context the, life cycle analysis (LCA) should be carried out to enhance the sustainability of the nanotechnology for construction industries.

KEYWORDS: Concrete, Glass, Nanomaterials, Nanosensors, Steel

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INTRODUCTION

Nanotechnology is a combination of science, engineering and technology. Nanotechnology is the study of phenomena and the manipulation of materials at nanoscale. Nanotechnology deals with the study and application of extremely small things and can be used across all the other science fields, material science, and engineering. The nanotechnology is not a new technology; it is the re-engineering of materials by controlling their shape and size at the nanoscale (Mann 2006). The key in nanotechnology is the size of particles because at the nanoscale, the physical, chemical, and biological properties of materials are unique and dramatically improved from the properties of individual atoms and molecules or bulk matter (Balaguru and Chong 2006). These properties are improved due to increase in relative surface area and new quantum effects.

Nanomaterials are core of nanoscience and nanotechnology. Nanomaterials are materials having at least one dimension between 1—100 nanometers but these can be nanoscale in one dimensions, two dimensions or/and three dimensions. There are some nanoparticles which occur naturally, but most practically used are synthetic nanomaterials. Synthetic nanomaterials having common types are nanotubes, quantum dots, nanowires and nanorods (Alagarasi 2011). There are different synthetic methods for nanomaterials. These methods can be split into two approaches "bottom up" and "top down". Broken down of bulk metal into powder and then into nanoparticles known as "top down" and having common example is mechanical grinding. This approach requires larger amount of materials and can lead to waste if excess material is discarded. In "bottom up" approach, atoms are combined into nanostructured arrays, which can be time-consuming but this approach has higher purity, better particle size/surface chemistry control as compared to "top down" approach. The common example of this

approach is self-assembly. Some new processes within the top-down and bottom-up approach are chemical vapour deposition, molecular beam epitaxy, atomic layer epitaxy, dip pen lithography, nanoimprint lithography and roll-to-roll processing.

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Nanotechnology based products can improve the current construction materials. Nanotechnology in construction is mainly focused on concrete having better properties using different nanomaterial (like: carbon nanotubes, silicon dioxide, nano flyash, zinc oxide, aluminum oxide, zirconium dioxide and ferric oxide nanoparticles), steel having better physical properties using copper nanoparticles and nano-sensors for concrete like smart nano dust (Ge and Gao 2008). The different applications of nanotechnology in construction are given following.

Concrete

The properties of concrete are strongly influenced by its nanomaterials. The development of various techniques makes it possible to analyze the properties of concrete at nano-level. The nanomaterials into concrete could improve its properties. Nano-SiO₂ could significantly increase the compressive strength of concretes by providing the large surface area for pozzolanic reaction as compared to silica fume and also act as a filler to improve microstructure (Jo et al 2007). Nano-SiO₂ could effectively absorb the calcium hydroxide crystals and increases the concentration of calcium silicate hydrate in concrete. The higher concentration of calcium silicate hydrates provides dense and strong concrete (Belkowitz and Armentrout 2010). The utilization of nano-flyash into concrete shows higher workability as compared to normal fly ash (Arulraj and Carmichael 2011). The use of nano- Al₂O₃ as partial replacement of cement upto 2% in blended concrete provides higher compressive strength compared to that of the concrete without nano- Al₂O₃ particles (Nazari et al 2010). Another nanomaterial is carbon nano tubes which when added in small amount in concrete provide better mechanical properties. The carbon nanotubes having two types: single walled carbon nanotubes and multiwalled carbon nanotubes. The 0.045% of multiwalled carbon nanotube into concrete can increase 66.3% of split tensile strength (Madhavi et al 2013).

Self Compacting Concrete (SCC) is concrete which flow itself due to its own weight. CuO nanoparticles as partial replacement of cement upto 4% improves the compressive strength of self-compacting concrete and reverses the negative effects of superplasticizer on compressive strength of the specimens. CuO nanoparticles accelerate C–S–H gel formation as a result of the increased crystalline Ca(OH)₂ amount at the early ages of hydration (Nazari and Riahi 2011). ZnO nanoparticles improve the pore structure of the self-compacted concrete and increase its mechanical strength (Arefi and Zarchi 2012).

Steel

Steel is a major part of the construction industry and nanotechnology helps to improve its properties, such as strength, corrosion resistance, and weld ability. The bridges or towers, whenever subjected to cyclic loading can lead to failure due to fatigue. Stress risers are responsible for fatigue failure. However, the use of copper nanoparticles can reduce the stress by providing better surface evenness. The high strength bolt having common problem is delayed fracture, which can be reduced by using vanadium and molybdenum nanoparticles. These nanoparticals reduce the embrittlement of grain boundaries in steel by small amounts of hydrogen and also improve the steel micro-structure. The addition of small amount of magnesium and calcium nanoparticles into steel matrix can improve the weld toughness (Mann 2006).

There are many companies worldwide, such as Sandvik, Arcelor Mittal, JFE steel, Nippon Steel's, NanoSteel and Metallicum which develop the steel based on nanotechnology. Sandvik Nanoflex is a precipitation-hardened steel alloy developed by Sandvik that depicts high strength, high formability and corrosion resistance. It is design for lightweight and rigid constructions. NANOHITEN is precipitation-hardened steel developed by JFE Steel Corporation. It uses nanometer-size, thermally stable carbide precipitates, which result in a material with enhanced strength and formability. MMFX2 Steel developed by MMFX Steel Corp provides twice the strength and five times more corrosion-resistance than conventional steel. However, Stainless steel provides same corrosion-resistance properties but due to its higher costs, the MMFX2 steel could be an alternative of stainless steel.

Nanosensors

Nanosensors used in construction to monitor or/and control the environment condition and the materials/structure performance (Liu et al 2007). One advantage of these sensors is their dimension (10^{-9} m to 10^{-5} m). Smart aggregate, a low cost piezoceramic-based multi-functional device, has been applied to monitor early age concrete properties such as moisture, temperature, relative humidity and early age strength development (Song et al 2008). A Piezoceramic transducer based smart aggregate is shown in Figure 1 (Hou et al 2012). An extension of this into the nanoscale envisages "smart nano-dust" which provides wide-scale monitoring in a co-ordinated smart network (Mann 2006).

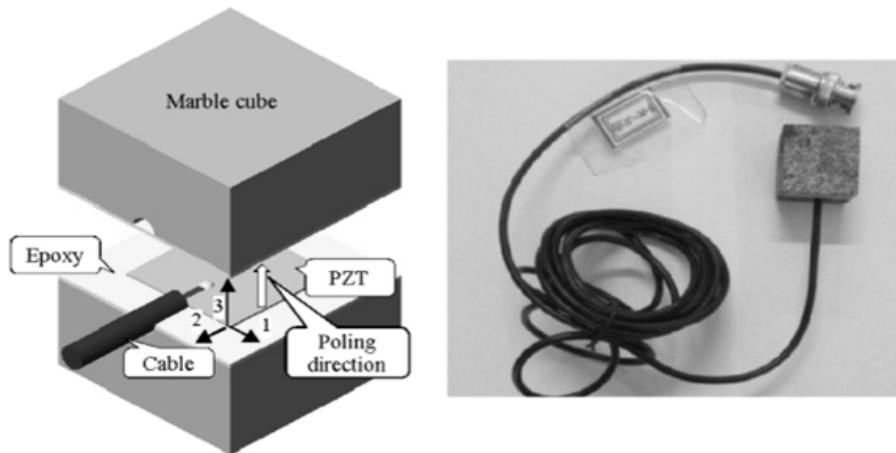


Figure 1: Piezoceramic Transducer Based Smart Aggregate

ENVIRONMENTAL ISSUES OF NANOTECHNOLOGY IN CONSTRUCTION INDUSTRY

Nanotechnology has number of challenges; among these main challenges are environment, health and cost. Nanoparticles might be non-biodegradable and on disposal, these disposed materials might form a new class of non-biodegradable pollutant and pose a new threat to the environment. In exacting, iron nanoparticles, which have a high surface area and high reactivity, are being used to transform and detoxify chlorinated hydrocarbons in groundwater. These nano-materials also have the potential to transform heavy metals such as soluble lead and mercury to insoluble forms. Nanomaterials are dangerous for human body. During the construction if nanoparticles enter in human body, they may pass through cell membranes or cross the blood-brain barrier because of their small size.

CONCLUSIONS

Nanotechnology is a rapidly expanding area of research which provides the unique properties of materials by controlling their shape and size at the nanoscale. The unique properties of nanomaterials provide its beneficial use in

construction industry. Although these materials are having unique properties but some of their limitations are high cost and they have adverse effect on environment and health. It is therefore utmost necessary to examine and estimates the risk from its production, use and disposal. In this context it is recommended that life cycle analysis (LCA) should be carried out to enhance the sustainability of the nanotechnology for construction industries.

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